Innovation, Catching-Up and Growth

by Jan Fagerberg

Norwegian Institute of International Affairs

P.O.B. 8159 DEP 0033 Oslo 1 Norway

Abstract

Most analyses of international differences in productivity growth present data for OECD countries only. Although defendable from a data-quality point of view, this implies that some important industrial countries that have grown fast in recent years are excluded from the analysis. To avoid this outcome the present study includes the most important NICs as well. Various indicators of economic and technological development and trends for the countries included in the analysis are presented. It is shown that although some convergence takes place, there are diverging factors at work as well. The formal model discussed above is then estimated on pooled time-series cross-country data for the period 1960-1985, and the consequences for analyses of international productivity differences and the slow-down in productivity growth in the 1970s are discussed.

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Introduction

This paper focuses on the contribution of innovation and diffusion of technology to growth of gdp and productivity.

On a theoretical level, the paper is an attempt to apply the Schumpeterian theory of innovation-diffusion, initially developed as an analysis of firm behaviour, to macro-economic growth. This application of the theory may be justified on two grounds. First, macro-economic data are made from micro-economic ones. To the extent that innovation-diffusion explains growth at the micro level, it should be expected to do so at the macro level as well. Second, nations are more than just statistical aggregates. The economic units that nations consist of are tied together by strong cultural, institutional and economic ties. Although increasingly contested by the trend towards transnationalization, nation-specific factors continue to significantly influence all aspects of economic activity, including the technological ones.[i] An obvious example of the importance of national factors, including technology policies, for technological and industrial change is of course Japan (Freeman, 1987), but similar - although often less flattering - examples may be found for other countries.

As emphasized by Schumpeter himself, his theory is confined to industrialized market economies. A few decades ago, there were few if any examples of important industrialized market economies outside the OECD area. This is no longer so. Several non-OECD countries compete today successfully in the international markets for manufacturing products. To exclude these countries from the investigation would be to overlook some of the most dynamic actors in the industrialized world today. This could, in turn, lead to wrong or biased conclusions on the determinants of growth of gdp and productivity in the industrialized world. Although problematic from a data-quality point of view, this paper attempts to include the most important industrialized market economies from the non-OECD area, the so-called NIC's, into the investigation.

The structure of the paper is as follows. The next section develops a formal model of economic growth based on the theoretical framework of the paper, followed by a discussion of data on technological levels and trends. Then the model is applied to a pooled cross-country time-series data set including data for 25 countries between 1960 and 1985. The final section contains summary and conclusions.

A Technology Gap Theory of Economic Growth

Essentially, the technology-gap theory of economic growth is an application of Schumpeter's dynamic theory of capitalist development, which was developed for a closed economy, to a world economy characterized by competing capitalist nation-states. Following Schumpeter, the technology gap theorists[ii] analyse economic development as a disequilibrium process characterized by the interplay of two conflicting forces: Innovation, which tends to increase economic and technological differences between countries, and imitation or diffusion which tends to reduce them. Whether a country behind the world innovation frontier succeeds in reducing the productivity gap vis-a-vis the frontier countries, does not only depend on its imitative efforts, but also on its innovative performance, and on the innovative performance of the frontier countries. Even if a country behind the world innovation frontier may succeed in reducing the productivity gap through mainly imitating activities, it cannot surpass the frontier countries in productivity without passing them in innovative activity as well. In general, the outcome of the international process of innovation and diffusion - with regard to the development levels of different countries - is uncertain. The process may generate a pattern where countries follow diverging trends, as well as a pattern where countries converge towards a common mean.

Assume that the level of production in a country (Y) is a multiplicative function of the level of knowledge[iii] diffused to the country from abroad (Q), the level of knowledge created in the country (T), the country's capacity for exploiting the benefits of knowledge (C), whether internationally or nationally created, and a constant (Z):

(4) $Y = Z\ Q^a T^b C^e$, where Z is a constant.

By differentiating and dividing through with Y:

$$(5)\ \frac{dY}{Y} = a\frac{dQ}{Q} + b\frac{dT}{T} + e\frac{dC}{C}$$

Assume further, as customary in the diffusion literature, that the diffusion of internationally available knowledge follows a logistic curve. This implies that the contribution of diffusion of internationally available knowledge to economic growth is an increasing function of the distance between the total level of knowledge appropriated in the country and that of the country on the technological frontier(for the frontier country, this contribution will be zero). Let the total amount of knowledge, adjusted for differences in size of countries, in the frontier country and the country under consideration be Q_f and Q^*, respectively. Then:

(6) $dQ/Q = h - h\ Q^*/Q_f$

By substituting (6) into (5) we finally arrive at:

$$(7)\ \frac{dY}{Y} = ah - ah\frac{Q^*}{Q_f} + b\frac{dT}{T} + e\frac{dC}{C}$$

Thus, following this approach, economic growth depends on three factors:

- The diffusion of technology from abroad. The contribution of this factor increases with the distance from the world innovation frontier.

- The growth in nationally produced knowledge.

- The growth in the country's capacity for exploiting the benefits offered by available technology, whether created within the country or elsewhere.

To what extent can this model be extended to cover productivity growth as well? According to Schumpeter the forces that determine growth of production determine growth of productivity too[iv], and this is what we will assume here. However, this may also be justified on other grounds. For instance, Kaldor has repeatedly argued that growth in labour productivity (dP/P) should be expected to be determined by growth in production (dY/Y) through the so-called "Verdoorn law":[v]

(8) $dP/P = m + n\ dY/Y$, where $n>0$ (economies of scale).

By substituting this equation into equation (7) we arrive at:

(9) $$\frac{dP}{P} = m + nah - nah\frac{Q^*}{Q_f} + nb\frac{dT}{T} + ne\frac{dC}{C},$$

which has the same structure as (7).

The technology-gap model of economic growth developed above does of course present a very simplified picture of reality. To do full justice to the Schumpeterian theory outlined above, the world economy should be modelled both from the technology side, characterized by creation, diffusion and contraction of competing technological systems, and from the side of competing nation-states, characterized by different technological levels and trends, institutional settings, and internal structural disequilibria. Admittedly, the model developed here is far from meeting these requirements.[vi] However, the model differs from the one which until now has dominated most empirical work on technological gaps and economic growth[vii] in at least one respect, it incorporates the effects of national innovative performance. As pointed out by Pavitt(1979/1980) and Pavitt and Soete(1982), the omission of the innovation variable in most applied work makes it difficult to explain diverging trends, whether represented by laggards, or related to the question of changes in technological leadership.

Data

In the preceding section, we defined two concepts related to a country's level of economic and technological development, the total level of knowledge appropriated in the country(Q^*), and the level of knowledge created within the country(T).

The first concept (Q*) refers to the total set of techniques in use in the country, whether invented within the country, or diffused to the country from the international economic environment. Q* cannot be measured directly. What can be measured, is the resources associated with the use of these techniques ("technology-input-measures") or the output of the process in which these techniques are used("technology-output-measures"). Of the former type, expenditures on education, research and development(R&D) and employment of scientists and engineers may be mentioned. But these data are often of low quality or do not exist at all, especially in the case of non-OECD countries. Indeed, regular time series from the early 1960s onwards exist for a small group of OECD countries only. Of the latter type, data on patents and productivity may be mentioned. However, since patents primarily reflect innovative (or inventive) activity, not imitation, patent-based measures give biased estimates of the level of technological development for countries which rely mainly on imitation (Fagerberg, 1988b). We have, therefore, chosen to use a productivity-based measure, Real GDP per capita, as a proxy for Q*. Since, current prices and exchange-rates are known to produce downward biased estimates of Real GDP per capita for countries with productivity levels well below the world productivity frontier, we adjusted the data on GDP per capita accordingly on the basis of results obtained by the "United Nations International Comparison Project".[viii]

The second concept(T) refers to the amount of technology created within the country, or its domestic "technology base" as opposed to its use of "imported technology". We will label this "national technological activity". This cannot be measured directly either. The most obvious proxies are R&D and patents. R&D reflects to some degree both innovation and imitation, since a certain scientific base is a precondition for successful imitation in most areas(Freeman(1982), Mansfield(1982)), while patents primarily reflect innovation, not imitation. Furthermore, R&D data do as noted not exist for several countries and time spans covered by our investigation. Thus, patents will be used. To avoid bias caused by differences in patent regulations across countries, the analysis will be confined to applications for patents by non-residents (external patent applications) in all countries reporting to WIPO.[ix]

There is, however, one serious problem related to the use of time series on patents. In 1978 two new international channels for filing patent applications, one European and one international, were added to the already existing national channels. There has always been some element of "economies of scale" in filing patent applications for the same invention in several markets, but with these new channels the importance of this factor increased. Earlier the applicant had to apply separately in each market. Now it became possible to file the application in one market and simultaneously get is registered as an application in other markets as well (so called "designations") at a small cost. Thus, we should expect the number of external patent applications filed through all channels combined to be inflated somewhat. As shown in Figure 1, the total number of external patent applications per capita filed through all channels combined (WIPO+EPO+PCT) grew rapidly from 1978 onwards (while the number of external patent applications per capita filed through the traditional national channels (WIPO) continued to decline). But we cannot conclude from this that the recorded increase in external patent applications from 1978 onwards is totally artificial. In fact also R&D as a percentage of GDP grew rapidly during the same period (Figure 2). Earlier studies have shown that R&D as percentage of GDP and the number of external patent applications, suitably deflated, are closely correlated both across countries and over time (Fagerberg 1987, 1988b). This leads us to believe that there has been an increase in the underlying level of national technological activity from the late 1970s onwards (although not so strong as the recorded increase in external patent applications through all channels combined may indicate).

As noted above, sine 1978 two new channels for filing patent applications have been present, an international one (PCT) and an European one (EPO). The empirically most relevant, however, is the latter. This introduces the possibility that the changes in patent regulations during this period have affected the European countries more strongly than other countries, since European firms naturally are more inclined to use an improved facility for filing patents in Europe than firms from other continents. To illustrate this, consider the regression below between growth in total external patent applications through all sources combined (TOTAL) as the dependent variable, and growth in external patent applications through the traditional national sources (WIPO), a dummy for the European countries, a dummy for the Non-European developed countries and a dummy for the NIC's as independent variables. The period is 1977-85 and 95% confidence-intervals are reported in brackets.

$$\underset{}{\text{TOTAL}} = \underset{(0.76/1.12)}{0.94\ \text{WIPO}} + \underset{(9.0/12.7)}{10.8\ \text{EUROPE}} + \underset{(5.8/11.2)}{8.5\ \text{OTHERDEVELOPED}} + \underset{(1.6/6.5)}{4.1\ \text{NIC}}$$

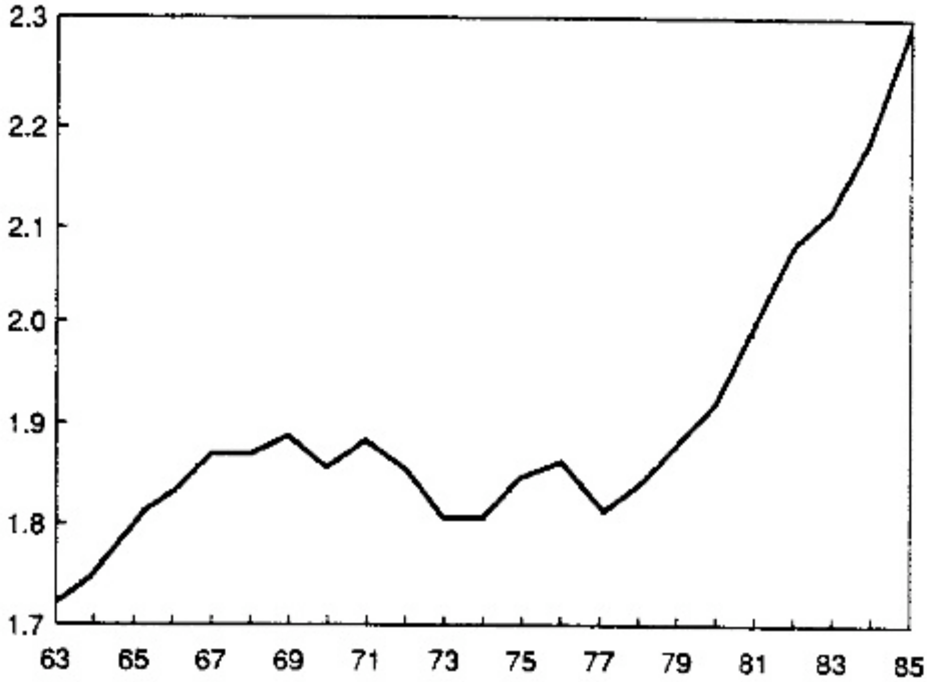
R^2 = 0.85 (0.81)

SER= 2.91

N = 25

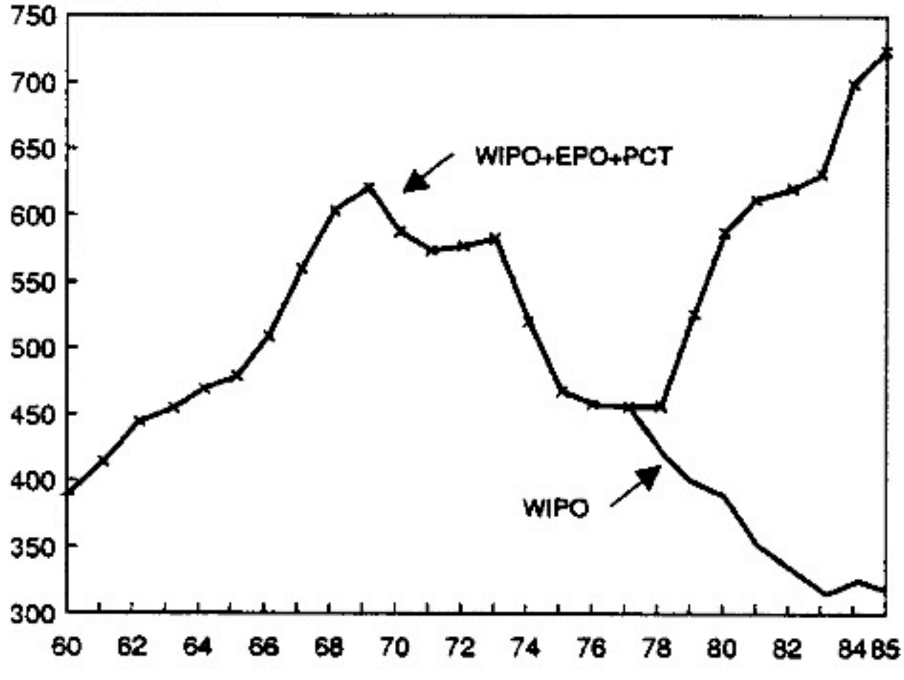
R&D IN PERCENTAGE OF GDP

10 OECD countries



EXTERNAL PATENT APPLICATIONS

10 OECD countries



This result clearly confirms that the new channels are used much more extensively by the European countries (and to some extent other developed countries as well) than by the NIC countries. Thus, to use the data without any kind of adjustment would probably introduce a bias both across countries and through time. We, therefore, decided to adjust the data by assuming that the "value" of one designation through EPO or PCT is equal to one half of a patent application filed through the traditional national channels. The adjusted number of external patent applications still showed an upward trend between 1979 and 1985, around 3 per cent per year as an annual average, which was around one half of the recorded increase without adjustment, but roughly the same as the average annual rate of growth in R&D as a percentage of GDP.

As in most other studies, the investment share(INV) was chosen as an indicator of the growth of the capacity to exploit the benefits of technology, whether domestically created or diffused to the country from abroad. This is, of course, a simplification since social and institutional factors are obviously very important for imitation and the associated structural changes to take place (Abramovitz, 1986). But the share of investment may also be seen as the outcome of a process in which social and institutional factors take part, i.e. differences in the size of the investment share reflect differences in social and institutional systems as well.

Testing the model

The model was tested on pooled cross-country time-series data for 25 countries for the period 1961-85. Average values of the variables covering entire business cycles were calculated, using the "peak" years 1968, 1973, 1979 and 1985 to separate one cycle from the next. This method, which was first used by Cripps and Tarling(1973), has been used in a number of studies on international differences in growth and productivity, including Cornwall(1976,1977), Cappelen et.al.(1984) and Michl(1985). The main argument in favour of the method is that it eliminates short-run fluctuations in the data, thereby facilitating the analysis of medium and long run dynamics.

Three different versions of the model were tested. Model I (basic model) is the one outlined earlier, while the second and third model allow for the inclusion of an additional variable reflecting changes in the macro-economic conditions from one time period to the next. Model II tests for the hypothesis that the growth of the countries included in the sample was significantly affected by the changes in terms of trade of industrialized countries during the period (terms-of-trade shock), while model III introduces the growth in world demand as a possible explanatory factor (demand shock). The latter is in accordance with the view, put forward by Maddison(1982) and others, that the economic slowdown after 1973 should partly be explained by too "cautious" economic policies. It may be regarded, then, as a more "Keynesian" version of the general technology gap model.

A special problem related to use of pooled data in regression analyses concerns the possibility autocorrelation in the residuals of each cross-sectional unit. When this occurs, it is often an indication of left-out variables. If these cannot be identified, it is common to adjust the data for the part of the total variance that can be attributed to left-out, country-specific factors. Several methods are available, including the use of first differences, country-specific dummy variables ("fixed effects models") and variance-components models ("random effects models").[x] The problem, of course, with these methods is that a large part of the total variance is left out of the investigation and attributed to unknown, country-specific factors. In this paper we have chosen the following procedure. To test for autocorrelation within the cross-sectional units we applied the Durbin-Watson statistics adjusted for gaps[xi]. If found to be significant, we identified the countries responsible for this, and applied a forward search by adding country-dummies to the equation one by one on the basis of their contribution to the estimated degree of autocorrelation. In each case the best model was assumed to be the one with least variance.

The countries included[xii] in the test were USA, Canada, Japan, Australia, New Zealand, Germany (Federal Republic of), France, United Kingdom, Italy, Austria, Belgium, Denmark, the Netherlands, Norway, Sweden, Switzerland, Finland, Ireland, Spain, Brazil, Argentina, Mexico, Hong Kong, Taiwan and Korea (Republic of).

The following variables were used:[xiii]

GDP = growth of gross domestic product in country i at constant prices,

PROD = growth of labour productivity in country i (defined as growth of gdp less growth of employment),

TG = gross domestic product per capita in country i at constant 1980 market prices, adjusted for differences in purchasing power of currencies, relative to the most developed country of the sample (range 0 - 1),

PAT = growth of patent applications from residents of country i in other countries (external patent applications), adjusted,

INV = gross fixed investment in country i as a percentage of GDP at constant prices,

W = growth of world trade at constant prices,

TERMS = growth of terms of trade for industrialized market economies.

The results are given in table 1. The first two regressions in the table report the results for the basic technology gap model outlined earlier. In both cases the coefficients turned up with the expected signs significantly different from zero at the 1% level. However, the Durbin-Watson statistics indicates auto-correlation in the residuals of the cross-sectional units. The next four regressions test the hypotheses of terms of trade and world demand as additional explanatory factors. Both hypotheses are supported, but the versions with world demand included have higher fits. However, autocorrelation continues to pose problems. The last six regressions, then, report results when dummies are included. Again, the model with world demand included is the most satisfactory when care is taken to the test for autocorrelation and the degree of explanation. Due to limitations of space, we do not report the results for the country dummies. However, the general impression is that the estimated coefficients are relatively robust to inclusion of new variables. The most notable difference is that the impact of the diffusion variable is strengthened when dummies are introduced.

TABLE 1. REGRESSION RESULTS

Basic model

GDP = 1.97	- 5.08TG	+ 0.13PAT	+ 0.19INV		R^2=0.58(0.56)
(1.26)	(0.83)	(0.03)	(0.05)		SER=1.62
***	*	*	*		DW(73)=1.33
					N=98

PROD = 0.66	- 1.75TG	+ 0.11PAT	+ 0.13INV		R^2=0.40(0.38)
(1.11)	(0.75)	(0.03)	(0.04)		SER=1.52
	**	*	*		DW(73)=1.17
					N=98

Testing for other factors

GDP = 2.01	-4.75TG	+0.09PAT	+0.23INV	+0.62TERMS	R^2=0.64(0.62)
(1.11)	(0.76)	(0.03)	(0.04)	(0.16)	SER=1.51
***	*	*	*	*	DW(73)=1.33
					N=98

PROD = 0.36	-2.00TG	+0.07PAT	+0.13INV	+0.68TERMS	R^2=0.52(0.50)
(1.01)	(0.68)	(0.02)	(0.04)	(0.14)	SER=1.37
	*	*	*	*	DW(73)=1.13
					N=98

GDP = 0.35	- 4.39TG	+ 0.11PAT	+ 0.18INV	+ 0.37W	R^2=0.75(0.74)
(0.95)	(0.63)	(0.02)	(0.04)	(0.05)	SER=1.26
	*	*	*	*	DW(73)=1.35
					N=98

PROD = -1.04	- 1.64TG	+ 0.09PAT	+ 0.12INV	+0.32W	R^2=0.62(0.60)
(0.93)	(0.61)	(0.02)	(0.04)	(0.04)	SER=1.22
	*	*	*	*	DW(73)=1.10
					N=98

Testing for country-specific effects

Model I

$$GDP^{a} = \underset{(1.11)^{*}}{3.01} - \underset{(0.81)^{*}}{5.61}TG + \underset{(0.03)^{*}}{0.11}PAT + \underset{(0.04)^{*}}{0.20}INV$$

$R^2=0.68(0.66)$
SER=1.44
DW(73)=1.58
N=98

$$PROD^{b} = \underset{(1.14)}{1.34} - \underset{(0.84)^{*}}{3.06}TG + \underset{(0.02)^{*}}{0.09}PAT + \underset{(0.03)^{*}}{0.14}INV$$

$R^2=0.57(0.52)$
SER=1.34
DW(73)=1.45
N=98

Model II

$$GDP^{a} = \underset{(0.99)^{*}}{2.74}-\underset{(0.73)^{*}}{6.00}TG+\underset{(0.02)^{*}}{0.06}PAT+\underset{(0.04)^{*}}{0.24}INV+\underset{(0.14)^{*}}{0.67}TERMS$$

$R^2=0.75(0.73)$
SER=1.29
DW(73)=1.75
N=98

$$PROD^{b} = \underset{(0.97)}{1.31}-\underset{(0.71)^{*}}{3.58}TG+\underset{(0.02)^{*}}{0.04}PAT+\underset{(0.03)^{*}}{0.19}INV+\underset{(0.12)^{*}}{0.72}TERMS$$

$R^2=0.70(0.66)$
SER=1.13
DW(73)=1.58
N=98

Model III

$$GDP^{a} = \underset{(0.77)}{1.15} - \underset{(0.55)^{*}}{5.44}TG + \underset{(0.02)^{*}}{0.08}PAT + \underset{(0.03)^{*}}{0.18}INV + \underset{(0.04)^{*}}{0.37}W$$

$R^2=0.86(0.84)$
SER=0.97
DW(73)=2.11
N=98

$$PROD^{b} = \underset{(0.83)}{-0.18} - \underset{(0.60)^{*}}{3.05}TG + \underset{(0.02)^{*}}{0.07}PAT + \underset{(0.03)^{*}}{0.13}INV + \underset{(0.04)^{*}}{0.32}W$$

$R^2=0.78(0.75)$
SER=0.96
DW(73)=1.72
N=98

Notes

a) Includes dummies for USA, Canada, Argentina and Hong Kong.

b) Includes dummies for Germany, France, Belgium, Spain, Australia, Argentina and Mexico.

*   = Significant at a 1% level(two-tailed test)

** = Significant at a 5% level(two-tailed test)

*** = Significant at a 10% level(two-tailed test)

R^2 in brackets = R^2 adjusted for degrees of freedom

SER = Standard error of regression

DW(N) = Durbin Watson adjusted for gaps

N = number of observations included in the test

Standard deviation of estimate in brackets.

Table 2 presents a calculation of estimated and actual growth for the average country of the sample, and table 3 presents a similar calculation for growth of labour productivity. The calculations are based on equation (7) and (9),[xiv] respectively, and the coefficients are taken from the six last regressions of table 1 (with dummies). The pure technology gap model (model I) is shown to predict a slowdown in growth of gdp and labour productivity of around one third of what actually occurred. The inclusion of changes in terms of trade (model II) improves the prediction for the 1973-79 period, but this model too fails to predict the slow growth of gdp and labour productivity in the most recent period. The model with growth of world demand included (model III), in contrast, fits the data quite well. According to this model, only around one fourth of the estimated slowdown in growth of gdp and productivity should be attributed to technological factors, the remaining being due to variations in demand.

Thus, the general conclusion is that when the demand variable is excluded, the model fails to predict more than a part of the actual slow-down in growth of gdp and productivity. This is especially so for the most recent period. Table 4 presents a test of the hypothesis that the data from the most recent period are not generated by the same model as the data from earlier periods for the models used in the preceding tables. The results suggest that we should accept the hypothesis of structural change when changes in terms of trade are included as one of the explanatory variables, otherwise not.

TABLE 2. GROWTH DECOMPOSED[a]

Model I:

	1960-68 I	1968-73 II	1973-79 III	1979-85 IV	Change IV-I
Contribution from:					
Diffusion	1.9	2.0	1.8	1.7	-0.2
Innovation	0.8	0.4	0.1	0.3	-0.5
Investment[b]	2.0	2.2	2.3	1.8	-0.2
Growth (est.)	4.7	4.6	4.1	3.8	-0.9
Growth (act.)	5.2	5.8	3.5	2.4	-2.8
Residual[c]	0.5	1.2	-0.6	-1.4	

Model II:

	1960-68 I	1968-73 II	1973-79 III	1979-85 IV	Change IV-I
Contribution from:					
Diffusion	2.0	2.1	1.9	1.8	-0.2
Innovation	0.4	0.2	0.0	0.2	-0.2
Investment[b]	2.3	2.6	2.7	2.1	-0.2
Terms of trade	0.4	0.0	-1.5	-0.5	-0.9
Growth (est.)	5.1	4.9	3.1	3.6	-1.5
Growth (act.)	5.2	5.8	3.5	2.4	-2.8
Residual[c]	0.1	0.9	0.4	-1.2	

Model III:

	1960-68 I	1968-73 II	1973-79 III	1979-85 IV	Change IV-I
Contribution from:					
Diffusion	1.8	1.9	1.7	1.7	-0.1
Innovation	0.5	0.3	0.0	0.2	-0.3
Investment[b]	2.2	2.3	2.4	1.9	-0.3
Demand[d]	0.6	1.3	-0.9	-1.2	-1.8
Growth (est.)	5.1	5.9	3.3	2.6	-2.5
Growth (act.)	5.2	5.8	3.5	2.4	-2.8
Residual[c]	0.1	-0.1	0.2	-0.2	

Notes
a) Columns do not always add due to rounding.
b) Including the constant term.
c) Actual growth less estimated growth.
d) Assumed to be zero for all four periods combined (1960-86).

TABLE 3. GROWTH OF LABOUR PRODUCTIVITY DECOMPOSED[a]

Model I:

	1960-68 I	1968-73 II	1973-79 III	1979-85 IV	Change IV-I
Contribution from:					
Diffusion	1.0	1.1	1.0	0.9	-0.1
Innovation	0.6	0.3	0.0	0.3	-0.3
Investment[b]	1.5	1.7	1.7	1.4	-0.1
Productivity Growth (estimated)	3.2	3.1	2.7	2.7	-0.5
Productivity Growth (actual)	4.0	4.2	2.2	1.7	-2.3
Residual[c]	0.8	1.2	-0.5	-0.9	

Model II:

	1960-68 I	1968-73 II	1973-79 III	1979-85 IV	Change IV-I
Contribution from:					
Diffusion	1.2	1.3	1.1	1.1	-0.2
Innovation	0.3	0.2	0.0	0.1	-0.2
Investment[b]	2.1	2.3	2.3	1.9	-0.2
Terms of trade	0.4	0.0	-1.6	-0.5	-0.9
Productivity Growth (estimated)	4.0	3.7	1.9	2.6	-1.4
Productivity Growth (actual)	4.0	4.2	2.2	1.7	-2.3
Residual[c]	0.0	0.5	0.2	-1.0	

Model III:

	1960-68 I	1968-73 II	1973-79 III	1979-85 IV	Change IV-I
Contribution from:					
Diffusion	1.0	1.1	1.0	0.9	-0.1
Innovation	0.5	0.3	0.0	0.2	-0.3
Investment[b]	1.7	1.8	1.9	1.6	-0.1
Demand[d]	0.6	1.2	-0.7	-1.0	-1.6
Productivity Growth (estimated)	3.8	4.4	2.2	1.7	-2.1
Productivity Growth (actual)	4.0	4.2	2.2	1.7	-2.3
Residual[c]	0.2	-0.2	0.0	0.0	

Notes
a) Columns do not always add due to rounding.
b) Including the constant term.
c) Actual productivity growth less estimated productivity growth.
d) Assumed to be zero for all four periods combined (1960-86).

TABLE 4. TEST FOR STRUCTURAL CHANGE (CHOW-TEST)

	GDP	Productivity
Model I	$F(25,65) = 2.00$	$F(25,65) = 1.29$
Model II	$F(25,64) = 2.76^{*}$	$F(25,61) = 2.13^{*}$
Model III	$F(25,64) = 0.94$	$F(25,61) = 0.76$

* = Acceptance of structural change, 1 % level

Concluding remarks

This paper has focused on the contribution of innovation and diffusion of technology to growth of gdp and productivity. The results confirm that both the scope for imitation, growth in national technological activities and increases in the capital stock have a significant impact on growth of gdp and productivity. This is consistent with earlier findings that a large part of the differences in growth between industrialized countries in the post-war period can be explained by these factors (Fagerberg, 1987, 1988b).

However, technological factors are mainly of a long run nature and should not be expected to explain large short- or medium-run variations in the growth of gdp and productivity. This is also confirmed. In fact, according to the calculations presented in this paper, less than one third of the actual slow-down in growth of gdp and productivity after 1973 can be explained by technology, the remaining being due to demand and other factors.

Thus, the results reported in this paper do not support the view[xv] that a large slowdown in productivity growth was to be expected in the 1970s due to a reduced technology gap. This, of course, does not imply that this factor has not been of importance for many developed countries. But as these countries approached the technology frontier, other, less developed, countries joined the industrialized world. For these countries, the prospects for high growth through exploitation of the technology gap continued to be high, provided that the macro-economic conditions of the world economy were of a kind that made this process possible. However, in contrast with the 1950s and 1960s, when high growth in demand, ample credit and trade liberalization went hand in hand, the early 1980s have witnessed slow growth in demand, tightening of credit and increasing protectionism via a vis countries in the process of industrialization. The findings of this paper are consistent with the view that these changes in global macro-economic conditions have significantly retarded the growth of industrializing countries and, through repercussions, also the growth of countries on a higher level development.

APPENDIX

Methods

Growth rates are calculated as geometric averages for the periods 1960-68, 1968-73, 1973-79 and 1979-85, or the nearest period for which data exist. Levels and shares are calculated as arithmetic averages for the periods 1960-67, 1968-73, 1974-79 and 1980-85, or the nearest period for which data exist.

Sources

a) Real GDP per capita, 1980 market prices in US $:

Taiwan: Statistical Yearbook of the Republic of China

Other countries: IMF International Financial Statistics

b) Growth of gross domestic product, at constant prices, Growth of civilian employment and Gross investment as share of GDP:

OECD-countries: OECD Historical Statistics

Hong Kong, Taiwan and Korea 1960-73: Chen, E.K (1979) Hyper-growth in Asian Economies London: MacMillan

Taiwan 1973-85: Statistical Yearbook of the Republic of China

Hong Kong and Korea (1973-85),
IMF International Financial Statistics and United Nations Statistical Yearbook for Asia and the Pacific (Growth of GDP and Investment as a share of GDP)
ILO Yearbook of Labour Statistics and World Bank World Tables (Growth of civilian employment)

Mexico, Argentina and Brazil:
IMF International Financial Statistics (Growth of GDP and Investment as a share of GDP)
United Nations Statistical Yearbook for the Latin America and the Caribbean (Growth of civilian employment)

The employment data for the non-OECD countries are generally not of the same quality as the OECD data. Different sources may imply large differences in the calculated growth rates. The data for Hong Kong and Korea are estimates based on the available sources. The data for Mexico, Argentina and Brazil are based on data for economically active population between 15 and 64 of age adjusted for changes in the unemployment rate (where known).

c) External patent applications:

OECD countries: OECD/STIIU DATA BANK

Other countries: World International Property Organization(WIPO): Industrial Property Statistics and unpublished data.

Data for the non-OECD countries are compiled from published WIPO statistics except for Hong Kong, Korea and Taiwan 1975-85 where data are compiled by WIPO from unpublished sources. For Ireland, Spain, Brazil, Argentina, Mexico and Hong Kong the data for the first period are for the years 1964-68. For Korea and Taiwan the data for the second and third periods are for 1969-75 and 1975-79, respectively.

d) R&D as percentage of GDP:

OECD countries: OECD/STIIU DATA BANK

e) Growth of world trade at constant prices:

The growth of total OECD imports was used as proxy. The data were taken from: OECD Historical Statistics

f) Growth of terms of trade of industrialized countries:

IMF International Financial Statistics (growth of export unit values less growth of import unit values)

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NOTES

i. Lundvall (1988) has coined the concept "national system of innovation" to characterize the systematic impact of nation-specific factors on technological and industrial change.

ii. The major contributors to the development of the "Technology Gap Theory" have been Gomulka(1971) and Cornwall(1976,1977), but the main arguments were outlined much earlier by Posner(1961), even if Posner's main concern was specialization, not growth.

iii. In the present context, knowledge means "technological know-how" (knowledge and skills on how to produce goods and services).

iv. According to Schumpeter, innovation-diffusion creates new demand and production, and this new demand creates new employment. ".. for the new demand, first of the entrepreneur and then of those who extend operations (..) is, directly and indirectly, chiefly demand for labor" (Schumpeter 1934, p.369). Hence, the basic model should be the same.

v. There is a large literature on this relationship and we will not attempt to summarize it here. Formally, this relation may be obtained by applying a static Cobb-Douglas production function and assuming a constant capital-output ratio, in which case the coefficient n will be positive, zero or negative depending on whether there are increasing, constant or decreasing returns to scale (see, for instance, Rowthorn, 1979). Kaldor's own view, however, is that the positive association between productivity growth and production growth is not only due to static economies scale but also to the fact that higher growth implies a higher rate of "learning by doing" (Kaldor, 1966, p. 9-10).

vi. See Fagerberg (1988a) for an attempt to extend the perspective outlined here to cover external trade/competitiveness as well.

vii. See Kendrick (1981), Maddison (1987) and Fagerberg (1988b) for surveys and discussion of previous work in this area.

viii. This was done by estimating a relation between real gdp (nominal gdp adjusted for differences in purchasing power of currencies) and nominal gdp on the data reported by Kravis et al. (1982) and using this relation to predict real gdp for the countries of our sample. For details, see Fagerberg (1988b) p. 454 (note 19).

ix. This implies that patent applications by Norwegian citizens in Norway, Danish citizens in Denmark etc. are deducted from the total number of patent applications filed in all countries.

x. For an overview, see chapter 10-3 in Johnston (1984).

xi. What this implies is that we leave out the differences between the residuals of different cross-sectional units and the corresponding residuals from both the numerator and the denominator, thereby reducing the number of observations with one per cross sectional unit.

xii. Because of lack of data, we have only 23 observations for the 1960-68 period (all countries except Taiwan and Korea), making a total of 98 observations.

xiii. See the appendix for details on definitions and sources.

xiv . The coefficient "m" in equation (9), representing technological progress not accounted for by diffusion and innovation of technology, is assumed to be zero.

xv. See, for instance, Marris (1982).